Density Effects on Performance to Release of Three Size Groups Within Populations of Pond-Reared Juvenile Coho Salmon. Smolts Released From Quinsam Hatchery in 1983

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DENSITY EFFECTS ON PERFORMANCE TO RELEASE OF THREE SIZE GROUPS WITHIN POPULATIONS OF POND-REARED JUVENILE COHO SALMON. SMOLTS RELEASED FROM QUINSAM HATCHERY IN 1983.

December 1984

by

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ABSTRACT

Fagerlund, U. H. M., J. R. McBride, B. S. Dosanjh, H. T. Bilton, R. B. Morley, and J. Van Tine. 1984. Density effects on performance to release of three size groups within populations of pond-reared juvenile coho salmon. Smolts released from Quinsam Hatchery in 1983. Can. Tech. Rep. Fish. Aquat. Sci. 1337: 19 p.

Juvenile coho samon (Oncorhynchus kisutch) were reared for 12 months at four loading densities in Burrows' ponds at Quinsam Hatchery, Vancouver Island. Representative numbers from sub-populations of small, medium and large size fish were marked with individually coded nose tags and all fish were released at end of May, 1983. This report provides information regarding growth, size distribution, mortality, food consumption, food conversion efficiency, body composition, interrenal activity and plasma cortisol concentrations of fish in the four groups. Returns of marked jacks and adults will be reported when they become available.

Key words: coho salmon, Oncorhynchus kisutch, smolt, culture, density, survival

RÉSUMÉ

Fagerlund, U. H. M., J. R. McBride, B. S. Dosanjh, H. T. Bilton, R. B. Morley, and J. Van Tine. 1984. Density effects on performance to release of three size groups within populations of pond-reared juvenile coho salmon. Smolts released from Quinsam Hatchery in 1983. Can. Tech. Rep. Fish. Aquat. Sci. 1337: 19 p.

Des saumons cohos (Oncorhynchus kisutch) juvéniles on été élevés pendant un an selon quatre régimes de chargement dans les étangs Burrows de la piscifacture de Quinsam (île Vancouver). Des échantillons représentatifs prélevés de sous-populations de petits, de moyens et de gros poissons ont été marqués avec des étiquettes nasales individuellement codées. Tous les poissons ont té relâchés à la fin de mai 1983. Le présent rapport contient des données sur la croissance, la fréquence des tailles, la mortalité, la consommation d'aliments, l'activité interénale et les concentrations de cortisol plasmatique chez les poissons des quatre groupes. L'information sur les remontées de jeunes mâles précoces et d'adultes marqués sera présentés dès qu'elle sera disponible.

Mots-clés: saumon cohos, Oncorhynchus kisutch, saumoneau, culture, densité, survie

INTRODUCTION

Crowding in fish husbandry has for some time been known to adversely affect growth and increase disease incidence. It has also been established that social interactions during crowded conditions may result in physiological and behavioral changes, which may affect fitness and survival. An example of the latter changes has been reported by Kalleberg (1958), who noted suppression of normal behavior patterns (aggression, territoriality) in hatchery reared Atlantic salmon, Salmo salar. The noted changes may affect ocean survival.

Fagerlund et al. (1983) in two separate studies with coho (O. kisutch) at Capilano Hatchery reported a strong relationship between ocean survival and ponding density during a 12 month rearing period, but only a weak relationship when differential densities were maintained for only five months before release into the ocean. When equal-numbered sub-populations of small, medium and large size fry were individually marked the adult survival rate of the small fish was markedly lower than that of the other two sub-populations. A distinct relationship between culture density and adult return rate was also noted in an earlier study with coho at Capilano Hatchery (Sandercock and Stone, pers. comm.).

Capilano Hatchery is supplied with water from the Capilano River and water temperatures drop to levels near freezing during the winter. In this communication we examine the effect(s) of varying ponding density on the performance of coho smolts reared at Quinsam Hatchery under conditions of higher water temperatures. The coho smolts produced in this system are generally 20-30% larger than those obtained from the Capilano Hatchery reflecting the influence of the warmer water conditions. Jack and adult return rates from the Quinsam Hatchery release will be reported at a later date.

MATERIALS AND METHODS

Eggs were obtained November 10 and 12, 1981 from Quinsam Hatchery broodstock. Emerging fry were randomly distributed among fibreglass rearing troughs at densities ranging from 80,000 to 100,000 fry per trough (69 to 86 L^{-1}). Between May 21 and June 1, 1982 the fry were randomly loaded into four Burrows' ponds (24.6 m x 5.6 m x 0.9 m) at the densities shown in Table 1. Water temperatures decreased from 10.6°C at time of ponding to 8.8°C in December and increased thereafter to 10.6°C at time of release. Fish were exposed to a natural photoperiod.

All groups received Oregon moist pellets (Moore Clarke Co., La Conner, Washington). The fish were originally fed according to the recommended OMP feeding schedule, but the ration was gradually reduced to produce fish of a targeted weight of 25 g at time of release. The fish loaded at the lowest density were initially larger than other groups. Consequently,

commencing in October the feeding rate for this group was reduced relative to that of the others in an attempt to minimize the size difference.

In November, 1982 fork-lengths of 1,000 fish from each pond were measured. After determining length distribution in the sample 5% of the fish from each end of the distribution curve were eliminated. The remaining fish were divided, according to length into three equal-numbered sub-groups, each comprising 30% of the original sample. About 10,000 fish of each size category from density-groups 1, 3 and 4 were marked by removing the adipose fin and coded wire nose tags were applied. In density group 2, three replicates of approximately 4,000 fish each were marked and tagged for each size category. The replication was done to conform with the design of previous size and time of release studies (Bilton and Coburn 1981; Bilton et al. 1982), and thus serve as an extension of these studies. Inventory, taken shortly after tagging by determining marked-unmarked ratios, indicated that the upper 95% confidence limit for the actual number ponded in group 4 was only 90.4% of the assumed number (Table 1). Consequently, up to the time of marking, the food rations (as % of body weight) for these fish were larger than those of the other groups.

To monitor growth and to obtain samples for analysis all fish in a pond were crowded into one end and an appropriate number of fish were removed in three separate nettings. Prior to May weights and fork-lengths of randomly sampled, anaesthetized fish were recorded after excess surface water had been drained briefly on cloth and sampled fish were then returned to the ponds. For proximate and other analyses sampled fish were separated into sub-groups of small, medium and large size fish. The length ranges of the sub-groups were determined from the length distribution in 150-fish samples. In May, however, 300 tagged fish were taken, drained on cloth, quickly frozen and stored in sealed plastic bags. Weights and lengths were determined after the fish had been identified as to size group by reading tags removed from partially thawed fish.

Condition factors were calculated for individual fish as $\frac{W}{L^{3,25}} \times 1000$

where W is weight in g and L is length in cm (Vanstone and Markert 1968).

Water flow was initially 1400 L min^{-1}, increasing to 2300 L min^{-1} before time of release in order to compensate for the increasing biomass.

Oxygen and ammonia concentrations (Table 2) were within acceptable levels when measured during 5 weeks prior to release of the fish.

Samples of 20-24 fish from each density group were challenged at the end of May, 1983 with 30‰ sea water and plasma sodium concentrations were measured 24 h after transfer (Clarke and Blackburn, 1977).

During the collection of plasma for cortisol determinations precautions were taken to prevent the sampling procedure from influencing cortisol levels. Determinations were carried out with a radioimmunoassay kit (Gamma Coat, Clinical Assays, Cambridge, Massachusetts).

Histological techniques used have been outlined by van Overbeeke and McBride (1971) and methods for proximate analysis by Higgs et al. (1979).

RESULTS

Samples taken shortly after ponding suggested that the fish loaded at the lowest density were larger than those of other groups (Table 3) and this size advantage persisted although subsequently food rations for this group were decreased in order to reduce the size differences. Also, density groups 1 and 3 were distinguishable from other groups by initially having significantly larger condition factors. These differences which occurred despite attempts to distribute the fish randomly demonstrate the difficulties encountered in maintaining random distribution when moving large numbers of fish in a hatchery.

At the end of the rearing period (Table 3) density-related differences in weight were not detected with the exception of the larger weight of density group 1 noted above. On the other hand, condition factors of the fish raised at the two lowest densities were moderately lower than those of the two other groups. Males and females did not differ significantly in weight or length but the difference between condition factors 5.21 and 5.25, respectively, (not shown in Tables) was significant (ANOVA, $\alpha = 0.028$).

Weight distribution of fish in all groups was positively skewed (Table 5) when determined shortly after ponding. Skewness decreased between June and September but increased to strongly positive values from then on until release time. Skewness of length was initially weaker than that of weight although still positive, but reached negative values in September. After that skewness gradually changed to positive values. Density did not affect skewness of either weight or length.

Analysis for kurtosis in weight and length distribution (not shown in tables) gave higher than normal values (indicating that the distribution curve has a narrow top) for weight at all times, but length distribution was nearly normal.

An analysis of correlation of condition factor on length (Table 6) showed that condition factors, when measured shortly after ponding, increased significantly with length of fish. In subsequent samples the relationship became negative. We have previously observed a negative correlation in coho raised in cold water at Capilano Hatchery, although in those fish the correlation was much weaker. Since smolting is associated with a decrease in condition factor we suggested that the observed negative correlation was an indication that the larger fish in the populations demonstrated greater sea water readiness than smaller fish. An analysis by size-group of Quinsam data from May also shows a negative correlation present at all densities. The correlation is strongest in the "small" and "medium" size-groups, suggesting that any problems in sea water adaptation should be more obvious in these groups than in the "large" size-groups.

Two periods of high daily mortalities occurred, one during the summer of 1982 and the other during April, 1983 (Table 1, Fig. 1). Both outbreaks were ascribed to Furunculosis infections. A strong correlation between mortality rate and ponding density was observed during both periods. All fish were treated with terramycin during outbreaks but treatment during

the summer outbreak, 1982 reduced daily mortalities only gradually.

Daily food consumption (g per fish, Table 1) showed a trend to increase with increasing density. Since, moreover, fish at the lowest density gained most weight the efficiency in converting food to wet fish weight was inversely proportional to density.

Between July and September, 1982 moisture content of coho juveniles had decreased (Table 7) while protein and lipid contents had increased. In samples taken in March and May an increase in moisture content was observed (Table 8, 9). Protein content had increased further during this time, but fat content had decreased, the decrease being pronounced between March and May. The changes in body composition after September were similar to changes observed in coho raised at Capilano Hatchery (Fagerlund et al. 1981, 1983) and were concomitant with decreasing condition factors during this period.

Samples obtained in July, 1982 (Table 7) demonstrated a significant decrease in protein content with increasing density. In September samples this trend was still evident, but the effect was not statistically significant. However, at this time moisture content increases and lipid content decreases were significantly correlated with increasing density. In samples taken in March and May, 1982 (Tables 8 and 9) density- or size-related trends in body composition were not evident. This is in contrast to the Capilano studies in wich both density and size affected body composition. The lack of size-effect may partly be explained by the restriction of rations for density-group 1 and the inadvertent increase in rations for density-group 4 (see Materials and Methods).

Cortisol concentrations in plasma obtained in September, 1982 (Table 10) from fish held at the two lowest densities were significantly elevated although the values indicated only low levels of stress. In February, 1983 cortisol concentrations in the two density-groups tested (low, high) suggested a moderate level of stress. In May, 1983 concentrations were slightly, although significantly raised in density-groups 2 and 4 and this trend was consistent when measurements were broken down into size-groups. The generally large standard deviations are a reflection of the wide range of cortisol values. With the exception of high concentration in a few fish, the elevated cortisol concentrations encountered in some groups do not suggest a pathological condition, but are probably responses to physical activity in areas adjacent to the ponds. This conclusion is supported by the absence of changes in interrenal tissue structure as discussed in the following section. However, if sustained, such elevated levels may lead to deterioration in the normal body function of the animals including lowered disease resistance.

Interrenal cell nuclear diameters (ICNDs) in samples obtained in February, 1983 (density-groups 1 and 4 only) were lower in medium size fish than in the other two size-groups (Table 11). Fish in the high density group at this time had slightly, but not significantly, larger ICNDs than other fish. In May differences between size-groups were insignificant, but increasing density was associated with small but significant increases in ICNDs. Although the observed density-related increases in interrenal activity are small in comparison with those resulting from acute stress (McBride et al. 1981), or those observed in one instance as a result of crowding (Fagerlund et al. 1981), they nevertheless suggest a response to density-related social interaction.

In a seawater challenge test carried out at end of May mean plasma sodium concentrations of the density-groups ranged from 165.4 to 166.7 mM L^{-1}. Differences between groups were not statistically significant. Sodium concentration in fresh water controls was 157.8 mM L^{-1}. There was no correlation between length of fish and sodium concentrations.

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TABLE 1. Number of fish ponded and performance data for experimental groups of coho juveniles raised at four densities.

	Density			
	1	2	3	4
No. of fish ponded				
assumed	72,000	98,375	119,791	143,936
actual	72,988	89,506	117,434	121,326
95% confidence limits:				
Lower	66,685	82,833	109,303	113,925
Upper	80,623	97,430	127,076	130,081
Mortalities (no.)	1,192	7,763	15,586	30,074
Mortalities (%)*	1.6	8.7	13.3	24.8
Weight gain (g)				
6/1/1982-5/24/1983	24.7	21.9	22.9	22.2
Food consumption (g/fish)				
6/1/1982-5/24/1983	37.5	41.5	39.6	45.1
Food conversion efficiency (g gain/g food)				
6/1/1982-5/24/1983	0.66	0.52	0.57	0.49

* Percent of actual initial density.

TABLE 2. Dissolved oxygen and total ammonia content of water entering and leaving density ponds. Mean ± SD of six weekly measurements April 13 - May 25, 1983. Average pH of out-flow water from ponds was 6.9 and average temperature was 10.7°C.

April 13 - May 25	Intake	Density group 1	2	3	4
Dissolved oxygen mg L^{-1}	10.9 ± 0.2	8.7 ± 0.5	8.0 ± 0.4	7.5 ± 0.6	7.1 ± 0.5
Total ammonia mg L^{-1}	0.008 ± 0.004	0.065 ± 0.022	0.077 ± 0.022	0.084 ± 0.020	0.098 ± 0.028

All ponds	April 13	April 20	May 4	May 11	May 18	May 25
Dissolved oxygen mg L^{-1}	8.3 ± 0.8	8.2 ± 0.7	7.9 ± 0.7	7.0 ± 0.9	7.7 ± 0.7	7.9 ± 0.6
Total ammonia mg L^{-1}	0.088 ± 0.017	0.073 ± 0.016	0.059 ± 0.015	0.103 ± 0.023	0.059 ± 0.013	0.105 ± 0.018

TABLE 3. Weights and condition factors of coho juveniles raised at Quinsam Hatchery. Sample size was 150, except 300 in May.

	Initial density									
	1		2		3		4		All densities	
Sampling date	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Weight (g)										
June 1, 1982	1.2[a*]	0.5	0.8[a]	0.4	0.9[a]	0.3	1.0[a]	0.4	0.9[a]	0.4
Sept. 22, 1982	11.0[c]	2.8	9.0[b]	2.4	8.0[b]	2.8	8.5[b]	2.8	9.1[b]	3.0
Dec. 15, 1982	15.6[e]	4.4	13.1[d]	3.6	13.0[d]	3.6	13.0[d]	3.1	13.7[c]	3.9
Mar. 9, 1983	20.0[g]	5.7	17.2[e,f]	5.2	18.0[f]	5.3	16.6[e,f]	4.8	17.9[d]	5.4
May 24, 1983	25.9[i]	5.6	22.7[h]	4.7	23.5[h]	5.7	23.2[h]	5.0	23.5[e]	5.2
Condition factor										
June 1, 1982	7.86[j]	0.64	6.96[h]	1.00	7.58[i]	0.75	6.89[h]	0.85	7.32[e]	0.91
Sept. 22, 1982	6.53[g]	0.56	6.50[g]	0.53	6.62[g]	0.66	6.59[g]	0.61	6.56[d]	0.59
Dec. 15, 1982	6.14[e,f]	0.48	6.24[f]	0.48	6.25[f]	1.09	6.24[f]	0.48	6.22[c]	0.68
Mar. 9, 1983	5.46[c,d]	0.61	5.99[e]	0.32	6.03[e,f]	0.31	5.68[d]	0.64	5.79[b]	0.54
May 24, 1983	5.22[a,b]	0.36	5.18[a]	0.37	5.36[b,c]	0.51	5.31[b,c]	0.47	5.24[a]	0.42

Two-way ANOVA (density, time) showed that both weight and condition factor was affected by density, time and density x time. Values carrying a common letter are not significantly different (Tukey's multiple range test, = 0.05).

TABLE 4. Numbers released, weights, lengths and condition factors of tagged coho juveniles. Samples were removed on May 24 and all fish were released on May 30, 1983.

Tag code	Density	Size group	No. of tagged fish released	Weight (g) X	Weight (g) SD	Length (cm) X	Length (cm) SD	Condition factor X	Condition factor SD	Sample N	Tag retention after 150 d %
2-19-63	1	Small	9282	21.3	3.3	12.8	0.6	5.32	0.36	89	
2-20-07	1	Medium	9329	25.5	3.5	13.6	0.6	5.22	0.33	87	92.9
2-20-08	1	High	9584	29.7	5.9	14.4	0.9	5.12	0.37	99	
8-21-16	2	Small	4003	19.5	3.1	12.6	0.7	5.27	0.37	117	
8-21-17	2	Small	4001	20.3	3.5	12.6	0.7	5.27	0.37	120	
8-21-18	2	Small	4018	19.5	3.2	12.4	0.7	5.27	0.37	81	
8-21-55	2	Medium	3890	20.9	2.8	12.8	0.6	5.18	0.40	97	
8-21-56	2	Medium	3707	23.0	3.9	13.2	0.7	5.18	0.40	91	94.7
8-21-57	2	Medium	3751	22.7	3.3	13.2	0.7	5.18	0.40	89	
8-21-58	2	Large	4074	25.3	4.2	13.7	0.7	5.09	0.33	124	
8-21-59	2	Large	4106	25.9	4.4	13.8	0.7	5.09	0.33	97	
8-21-60	2	Large	4010	27.1	5.0	13.9	0.8	5.09	0.33	106	
2-20-09	3	Small	9405	20.1	3.8	12.5	0.8	5.45	0.45	92	
2-20-10	3	Medium	9471	24.0	4.6	13.3	0.8	5.29	0.60	120	95.3
2-20-11	3	Large	9860	27.3	7.0	13.7	1.0	5.35	0.42	72	
2-19-60	4	Small	8281	20.5	3.9	12.7	0.8	5.31	0.56	86	
2-17-62	4	Medium	8229	23.1	4.4	13.1	0.8	5.39	0.50	70	87.0
2-19-62	4	Large	8093	25.5	5.0	13.6	0.8	5.24	0.39	103	

Three-way ANOVAs (density, sex, size-group) showed that weight and length was affected by density, density x sex, size-group and density x size-group.
Condition factor was affected by density, sex and size-group, but the effect of density x size was only marginal at = 0.0514.

TABLE 5. Skewness (g, Snedecor and Cochran 1971)) in weight and length of samples of coho juveniles. Sample size was 150 except in May as noted in brackets. For method of sample selection refer to Materials and Methods.

Time	Initial density 1	2	3	4	All ponds Mean	SD
Weight						
June 1, 1982	0.52*	0.70*	0.81*	0.40*	0.61[a,b]**	± 0.18
Sept. 22, 1982	0.32*	0.34*	0.04	0.02	0.16[a]	± 0.20
Dec. 15, 1982	0.98*	0.73*	0.39*	0.22	0.58[a,b]	± 0.34
Mar. 9, 1983	0.69*	1.10*	0.88*	0.48*	0.79[b]	± 0.26
May 24, 1983	1.18*	0.68*	0.84*	0.74*	0.86[b]	± 0.22
	(300)	(1000)	(300)	(300)		
All times Mean	0.67	0.71	0.64	0.37		
SD	± 0.26	± 0.27	± 0.47	± 0.27		
Length						
June 1, 1982	-0.01	0.37*	0.36*	0.07	0.20**	± 0.20
Sept. 22, 1982	-0.45*	-0.40*	-0.85*	-0.69*	-0.60[a]	± 0.21
Dec. 15, 1982	-0.06	-0.03	-0.64*	-0.21	-0.24[a,b]	± 0.28
Mar. 9, 1983	0.15	0.31*	0.13	0.04	0.16[b,c]	± 0.11
May 24, 1983	0.33*	0.26*	0.39*	0.40*	0.35[c]	± 0.07
	(300)	(1000)	(300)	(300)		
All times Mean	0.005	0.10	-0.13	-0.08		
SD	0.31	0.32	0.57	0.40		

* Significantly different from 0.

** Two-way ANOVA (time, density) indicated significant effect of time on skewness of weight and length. Values carrying a common letter are not significantly different (Tukey's test, $\alpha = 0.05$).

TABLE 6. Linear regression of condition factor on length of juvenile coho. Values are covariate slopes, standard errors (SE) and numbers of observations (N). For method of sample selection refer to Materials and Methods.

Time	Slope	SE	N
June 1, 1982	0.24[d*]	0.04	600
Sept. 22, 1982	- 0.22[a,b]	0.02	600
Dec. 15, 1982	- 0.27[a]	0.02	600
Mar. 9, 1983	- 0.16[b,c]	0.02	600
May 24, 1983	- 0.14[c]	0.01	1822

* A three factor analysis (density, time, length) of covariance performed as a two-way analysis on both means and covariate slopes showed significant effects on slopes of time and density x time. The effect of density was not significant at $\alpha = 0.07$. Values carring a common letter are not significantly different (Bonferroni's test, $\alpha = 0.05$).

TABLE 6. cont. (linear regression)

May 24, 1983

Initial no. of fish	Size-groups: Small Slope	SE	N	Medium Slope	SE	N	Large Slope	SE	N	All groups Slope	SE	N
72,988	- 0.18	0.06	89	- 0.15	0.07	87	- 0.12	0.05	99	- 0.17	0.03	275
89,461	- 0.17	0.03	315	- 0.19	0.04	277	- 0.09	0.03	327	- 0.16	0.02	919
117,424	- 0.21	0.05	92	- 0.20	0.05	120	- 0.03	0.05	72	- 0.13	0.02	284
121,299	- 0.27	0.05	86	- 0.28	0.06	70	- 0.11	0.05	103	- 0.19	0.03	259
All densities	- 0.20[a]**	0.02	582	- 0.21[a]	0.02	554	- 0.09[b]	0.02	601			

** A four factor analysis of covariance (density, sex, size-group, length) performed as a three-way analysis on both means and covariate slopes showed a significant effect of size on slopes. Values carrying a common letter are not significantly different (Bonferroni's test, $\alpha = 0.05$).

TABLE 7. Body composition (%) of juvenile coho taken from Quinsam Hatchery. Values are means and standard errors of the mean (SEM) of 5 samples in July or 3 samples in September. Each sample consisted of five fish.

	Initial density 1	2	3	4	Row means
July 18, 1982					
Moisture	75.50	76.04	76.16	76.39	76.04
Protein*	15.18	15.47	14.76	14.79	15.05
Lipid	6.87	6.25	6.61	6.23	6.49
Ash	2.31	2.32	2.28	2.17	2.27
SEM			0.28		0.14
Sept. 22, 1982					
Moisture*	72.19	72.82	73.11	73.66	72.95
Protein	16.28	16.00	15.88	15.70	15.96
Lipid*	8.94	8.93	8.23	8.02	8.53
Ash	2.10	2.17	2.29	2.25	2.20
SEM			0.25		0.13

* One-way ANOVAs ($\alpha = 0.05$) showed that the indicated body constituents were affected by density.

TABLE 8. Body composition (%) of juvenile coho taken March 9, 1983 from Quinsam Hatchery. Values are means and standard errors of the mean (SEM) of two samples, each consisting of four fish.

Sub-group	Initial density 1	2	3	4	Row means
Moisture					
Small	74.10	75.21	75.05	75.06	74.85
Medium	73.67	74.86	74.28	74.53	74.34
Large	72.78	73.73	74.09	73.47	73.52
SEM		0.30			0.15
Column means	73.72	74.60	74.47	74.35	
SEM		0.17			
Protein					
Small	16.03	16.72	16.36	16.28	16.35
Medium	16.05	16.31	15.95	16.40	16.18
Large	17.07	16.72	16.75	17.03	16.89
SEM		0.22			0.01
Column means	16.39	16.58	16.36	16.57	
SEM		0.02			
Lipid					
Small	6.88	6.29	6.01	5.75	6.23
Medium	7.22	6.31	7.20	6.33	6.76
Large	7.25	6.72	6.82	7.21	7.00
SEM		0.35			0.03
Column means	7.11	6.44	6.68	6.43	
SEM		0.04			
Ash					
Small	2.19	2.61	2.37	2.37	2.38
Medium	2.31	2.71	2.53	2.37	2.48
Large	2.25	2.42	2.32	2.39	2.34
SEM		0.14			0.07
Column means	2.25	2.58	2.41	2.38	
SEM		0.08			

* Two-way ANOVAs showed significant effects of the following variables ($\alpha = 0.05$):

Body constituent	Variable
Moisture	Density, size, density x size
Protein	Size
Lipid	Size

TABLE 9. Body composition (%) of coho smolts taken May 24, 1983 before release from Quinsam Hatchery. Values are means and standard errors of the mean (SEM) of eight samples, each made up of 3 fish. Fish were separated into size-groups by reading nose tag codes.

Sub-group	Initial density 1	2	3**	Row means
Moisture				
Small	77.69	77.43	77.39	77.51
Medium	76.67	77.60	77.31	77.19
Large	77.66	77.61	76.92	77.40
SEM		0.22		0.13
Column means	77.34	77.55	77.21	
SEM		0.13		
Protein				
Small	17.72	17.53	17.57	17.60
Medium	17.70	17.43	17.52	17.55
Large	17.44	17.39	17.92	17.58
SEM		0.19		0.11
Column means	17.62	17.45	17.67	
SEM		0.11		
Lipid				
Small	2.29	2.79	2.22	2.43
Medium	3.35	2.47	2.50	2.77
Large	2.59	2.55	2.78	2.64
SEM		0.17		0.10
Column means	2.74	2.60	2.50	
SEM		0.10		
Ash				
Small	2.86	2.77	2.88	2.84
Medium	2.70	2.85	2.96	2.83
Large	2.97	2.92	2.75	2.87
SEM		0.08		0.05
Column means	2.83	2.85	2.86	
SEM		0.05		

* Two-way ANOVAs showed significant effects of the following variables ($\alpha = 0.05$):

Body constituent	Variable
Moisture	Density x size
Protein	Density, density x size
Lipid	Density x size

** Samples from density-group 4 were accidentally destroyed.

TABLE 10. Cortisol concentration (Mean ± SD, ng/ml) in plasma of juvenile coho raised at Quinsam Hatchery. N was 20 in September and 22 - 27 in May.

Size-group	Initial density 1	2	3	4	All ponds
September, 1982					
All sizes	51.4[a]* ± 19.1	46.2[a] ± 23.4	23.9[b] ± 5.2	29.6[b] ± 8.8	37.8 ± 19.4
February, 1983					
Small	80.1 ± 23.4			63.6 ± 31.3	
Medium	69.1 ± 29.6			104.6 ± 20.3	
Large	98.3 ± 32.8			84.8 ± 29.7	
All sizes	82.5 ± 42.6			84.3 ± 31.5	
May, 1983					
Small	21.9 ± 22.1	31.8 ± 24.1	23.1 ± 11.9	31.8 ± 25.1	27.0 ± 21.7
Medium	18.0 ± 11.3	37.2 ± 26.4	24.6 ± 12.6	35.5 ± 26.9	29.0 ± 22.0
Large	21.6 ± 13.0	33.9 ± 31.5	27.8 ± 11.1	31.0 ± 20.8	28.7 ± 20.6
All sizes	20.5[a] ± 16.4	34.4[b] ± 27.1	25.3[a] ± 11.9	32.9[b] ± 24.2	28.3 ± 21.4

* September, 1982: Two-way ANOVA (density, location in pond) indicated an effect of density.
February, 1983: Two-way ANOVA (density, size group) indicated no effect of either variable.
May, 1983: Two-way ANOVA (density, size-group) indicated an effect of density.

Values within rows carrying a common letter are not significantly different (Tukey's test, $\alpha = 0.05$).

TABLE 11. Interrenal cell nuclear diameters (um) of juvenile coho raised at Quinsam Hatchery. Values are means of 25 measurements from each of 15 fish sampled in February or 21-28 fish sampled in May, 1983. For method of sample selection see Materials and Methods.

	Initial density								All densities	
	1		2		3		4			
Size-group	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
February										
Small	6.226[b],*	0.272					6.217[b]	0.282	6.222[b],*	0.277
Medium	6.136[a]	0.204					6.152[a]	0.235	6.144[a]	0.220
Large	6.175[a]	0.227					6.225[b]	0.215	6.200[b]	0.223
All sizes	6.179	0.239					6.198	0.248	6.189	0.243
May										
Small	6.188	0.037	6.197	0.035	6.192	0.029	6.208	0.045	6.196	0.037
Medium	6.179	0.026	6.185	0.039	6.212	0.050	6.214	0.057	6.198	0.047
Large	6.189	0.037	6.190	0.028	6.208	0.030	6.227	0.068	6.204	0.046
All sizes	6.185[a]	0.033	6.191[a,b]	0.034	6.204[b,c]	0.039	6.217[c]	0.058	6.200	0.044

* February: Two-way ANOVA (density, size-group) indicated a significant effect of size. The effect of density was not significant at = 0.06. Values carrying a common letter are not significantly different (Bonferroni's t - test).

May: Two-way ANOVA (density, size-groups) indicated significant effect of density. Values carrying a common letter are not significantly different (= 0.05).

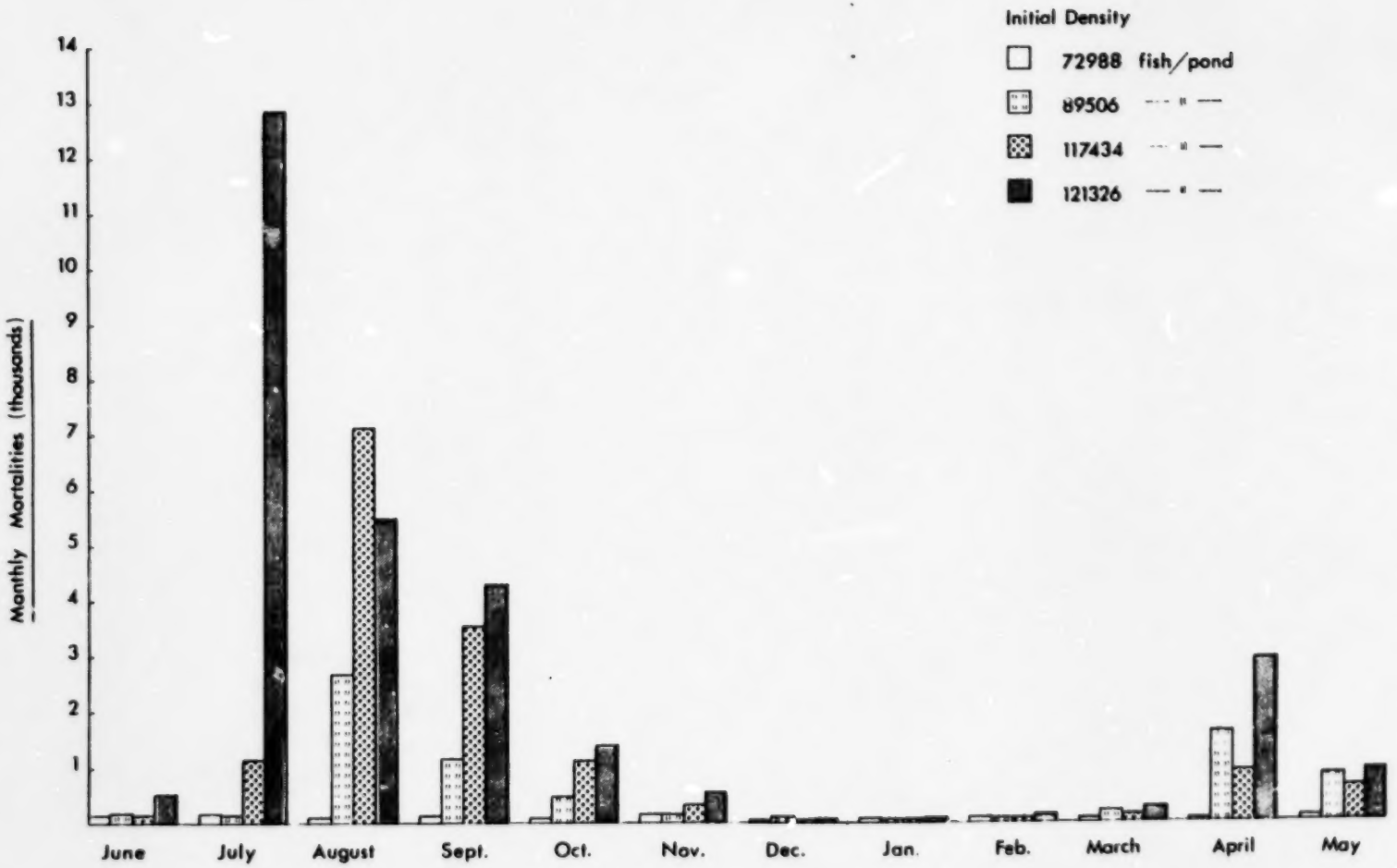

Figure 1. Monthly mortalities (thousands of fish per pond) during June 1982 - May 1983 for juvenile coho raised at 4 densities at Quinsam River Hatchery.